SYMPOSIUM ON DISTRIBUTED SIMULATION FOR MILITARY TRAINING OF TEAMS/GROUPS

THE ENGINEERING OF A TRAINING NETWORK

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ABSTRACT

This presentation describes the architecture and engineering development of the Multi-Service Distributed Training Testbed (MDT2). It summarizes the basic principles underlying Distributed Interactive Simulation (DIS) and the major components of MDT2. It then discusses the problem of simulator interoperability and describes some of the interoperability problems encountered in developing MDT2. MDT2 demonstrates that widely dissimilar training devices can be successfully linked to create a virtual testbed for training research.

INTRODUCTION

The Multi-Service Distributed Training Testbed (MDT2) relies on Distributed Interactive Simulation (DIS). DIS technologies allow us to link geographically separated simulators together to form networks of interacting simulators. The end result is a "virtual" laboratory using the unique resources from a number of different sites concurrently. Such virtual laboratories can support a variety of training and human factors research.

Although MDT2 is a research effort focusing on distributed training methods and strategies, it also has a physical component. This physical component is the simulators and communication networks that provide the underlying synthetic environment used for MDT2 research. Physically, MDT2 is a simulation system developed to support multi-service close air support (CAS) training research.

The purpose of this paper is to provide an overview of MDT2 as a simulation system. First, it reviews the basic principles underlying DIS. Then it summarizes the major technical requirements and the simulator network used to support CAS training research. Finally, it discusses some problems of simulator fidelity and interoperability encountered with MDT2.

THE MDT2 TESTBED

Distributed Interactive Simulation

MDT2 required a number of simulators at different sites across the United States to interact with one another in real-time. DIS technology provides a means for such interaction regardless of whether the various simulators are in adjacent rooms or 2,000 miles apart.

DIS represents an extension of the Simulation Networking (SIMNET) program developed by the Defense Advanced Research Projects Agency (Alluisi, 1991). Greatly simplified, DIS relies on the following principles (see Loral, 1992, for additional details):

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15. SUBJECT TERMS
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1. There is no central computer maintaining absolute truth and telling each simulator how its actions influence others.

2. Each simulator transmits the truth about its state, movements, and actions. Receiving simulators determine whether they can detect that information and what affect it has on them.

3. Information about nonchanging objects (e.g., terrain) is known by all simulators and therefore is not transmitted between simulators. Each simulator broadcasts its unique state, movement, and action to other simulators using standardized Protocol Data Units (PDUs).

4. Each simulator estimates or "dead-reckons" the position of other simulators. Each simulator maintains a dead-reckoning model of itself and regularly compares its actual state with the dead-reckoned model. Whenever a significant difference exists between the actual and dead-reckoned states, the simulator broadcasts state update information.

5. Each simulator creates an appropriate environmental representation based on the information received from other simulators and its own state information. Each simulator creates its own virtual world using standard simulator technologies (i.e., computer image generation, display, communication, and host computers).

MDT2 Simulation Network

The Multi-Service Distributed Training Testbed (MDT2), illustrated in Figure 1, consisted of four geographically separated sites. Two communication networks linked these sites together. One network used the Defense Simulation Internet (DSINet). The DSINet interconnected simulators in the Mounted Warfare Testbed (MWTB) at Fort Knox, KY and the Naval Air Warfare Center (NAWC) at Patuxent River, MD. It also linked these simulation sites with the data recording and observation facilities at the Institute for Defense Analysis (IDA) in Alexandria, VA. The second network used a commercial T-1 line to connect the simulators at the Armstrong Laboratory (AL) in Mesa, AZ to the NAWC. In addition to providing one of the simulators used during MDT2, the NAWC also served as a bridge between AL and the DSINet. This allowed information to flow between the two networks. The result was one fully integrated wide area network (WAN) in which all sites shared the same simulator data.

Standard communication hardware and software connected each site to the WAN. In addition, each site also used Defense Security Agency approved encryption hardware and software. This encryption equipment was necessary because both NAWC and AL had flight simulator software classified Secret No Foreign. As a result of this software, the entire MDT2 network operated at the Secret No Foreign level.

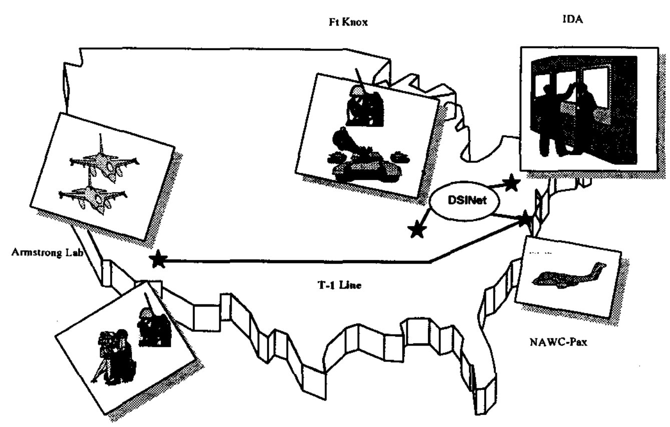

Figure 1. MDT2 Wide Area Network

Technical Requirements

The objective of the engineering portion of the MDT2 program was to establish a virtual testbed for training research using DIS-based technology. To accomplish this objective, the MDT2 team regularly met to identify the technical requirements for implementing MDT2. These meetings produced the following technical requirements:

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1. Existing simulators would form the foundation of MDT2. These simulators would be:

a. Virtual ground vehicle simulators (tanks and infantry fighting vehicles), computer generated enemy armor forces, and a battalion tactical operations center located at the MWTB.

b. A virtual OV-10 aircraft simulator, providing airborne forward air control, from the NAWC.

c. Two virtual F-16 aircraft simulators providing close air support and a Deployed Forward Observer-Modular Unit Laser Equipment (DFO-MULE) virtual simulator providing target detection and laser guided munitions support at Armstrong Laboratory.

d. A data logging and observation node at the IDA.

2. All simulator sites would interoperate with each other as part of a secure, real-time simulator network as specified by the DIS Standard 2.0.3 (University of Central Florida, 1993). Information would be transmitted between sites using Entity State, Detonate, Fire, Laser, Message, Event, Start/Resume, Stop/Freeze, and Acknowledge Protocol Data Units (PDUs).

3. A laser PDU would be implemented so that a Laser Guided Bomb simulation (executed by the shooter) could realistically acquire and track the laser spot generated by another simulator.

4. Ground and air vehicle positions, velocity, orientation, and type would be displayed based on Entity State PDUs received over the network.

5. Munitions would be processed, damage assessed, and blast effects displayed as appropriate.

6. Tactical and administrative voice communication between simulator nodes would be available in real-time.

7. Terrain databases would be sufficiently correlated to allow all participants to interact with one another in a common virtual world representing the National Training Center at Ft. Irwin, CA.

8. AL would provide radar emissions for the surface-to-air threats generated at the MWTB.

9. MWTB would translate DIS 2.0.3 protocols into the Simulator Network (SIMNET) protocols used on their local area network.

10. The simulation data and tactical voice communication between sites would be recorded for post-exercise analysis.

11. A video teleconferencing system would be available for post-mission after action reviews.

SIMULATOR INTEROPERABILITY

DIS protocols and WANs provide the means of transmitting information between simulators. This ability to exchange information is necessary in order for simulators to interoperate with one another. Implementing DIS protocols and establishing WANs, however, are not sufficient to ensure that the simulators and their human operators are interoperating with one another correctly or that the synthetic environment is responding as intended. It is also necessary to determine whether or not the virtual worlds within each simulator are sufficiently correlated with one another and with the underlying synthetic environment to provide the appropriate stimuli, responses, and feedback necessary for training. Thus the problem of simulator interoperability involves the classic problem of simulation fidelity (Hayes & Singer, 1989).

MDT2 was built around existing simulators engineered to meet service-specific training requirements. As a result, the fidelity of the simulators used in MDT2 varied greatly. These differing levels of fidelity had three significant impacts on the MDT2 program. First, they placed constraints on the design of training scenarios. Unconstrained training scenarios would simply have exceeded the processing and display capabilities of several simulators and prevented the participants from realistically performing mission critical tasks. Second, simulator hardware and software were modified to minimize selected fidelity differences. These modifications improved the extent to which the participants in MDT2 could share a common virtual world. Third, these fidelity differences necessitated an extensive period of testing between sites. This testing was required to establish the degree to which a common synthetic environment existed between simulators.

There were a number of fidelity differences between the various MDT2 simulators. These included computer image generation, visual displays, munitions, and radar simulation. Each of these differences caused significant impacts on the development, testing, and use of MDT2. Two of these fidelity differences are discussed below to illustrate typical problems that are likely to be encountered when using a heterogeneous network of simulators. This discussion also identifies the specific solutions implemented for MDT2.

Computer Image Generation and Displays

There are a wide variety of different computer image generators (CIGs) and display systems used within the simulation community. These various combinations of CIGs and displays were engineered to meet cost/performance requirements for specific applications. As a result of CIG and display differences, different simulators render different virtual representations of the same underlying synthetic environment. Table 1 is a qualitative summary of some of the differences in MDT2 simulator capability related to differences in CIGs and displays.

Table 1. Impact of CIG and Display Factors on MDT2 Simulator Capabilities

Simulator Variable	Simulator			
	Armor	OV-10	DFO-MULE	F-16
Terrain Detail	Medium	Low	High	Low
Moving Vehicles	High	Medium	Low	Medium
Viewing Distance	Low	Medium	Medium	Medium
Field of View	Medium	Low	Low	High
Field of Regard	Medium	High	Low	High
Display Resolution	Medium	High	Medium	Medium

One result of using different image generators and displays during MDT2 was that different simulators provided different levels of terrain detail. The DFO-MULE used photographs of actual areas from the National Training Center and extensive elevation data to create a highly detailed visual image. The aircraft simulators, on the other hand, used much coarser elevation data, while the simulators at the MWTB used an intermediate level of elevation data. Consequently, a tank from Ft Knox might be "flying" above the terrain in the DFO-MULE's view yet be the terrain for the aircraft.

One solution to this problem is to reduce all the computer generated data bases to the lowest level of terrain resolution. This would have greatly reduced the apparent realism of the terrain for the ground forces. Therefore, we modified the simulators to "adjust" the elevation of ground entities and explosions so that they were correctly display for each simulator's local view of the terrain.

A more serious problem with the different CIGs used in this project was the number of moving vehicles they could display. The number of moving vehicles that each simulator could display at any one time varied greatly between the different sites.

The DFO-MULE could display a maximum of five vehicles while the simulators at the MWTB could display an essentially unlimited number of vehicles. Increasing the number of vehicles that the DFO-MULE could process and display was technically unfeasible given MDT2's budget and schedule. Therefore, the scenarios were designed to limit the number and type of vehicles that the DFO-MULE would have to process. These processing limitations and scenario restrictions limited the DFO-MULE's participation during MDT2.

Interoperability Testing

The MDT2 team identified many of the technical factors limiting simulator interoperability early in the project. This allowed them to modify simulators or scenarios to reduce the negative impacts of these limitations. Other problems, however, only became apparent when the simulators were on-line for interoperability testing between the sites.

For example, during interoperability testing we discovered vehicles driving down a road in MWTB simulators were often as much as 300m off the road in AL's simulators. Detailed investigations prior to the start of training revealed that the Army and the Air Force used different government supplied source material to create the terrain databases used in MDT2. Each set of source materials represented standard digital cartographic information normally used for database development. However, separate agencies had compiled this information at different times and from different sources. As a result there were significant differences in the road's location and shape.

Interoperability testing also identified problems involving weapon effects, dead reckoning algorithms, and position updates. These problems point out that interoperability testing is a critical phase of any DIS-based project.

SUMMARY

Using a DIS-based simulation is not yet an "off-the-shelf" capability for the human factors professional. Such simulations are "custom-made" applications tailored to meet specific research needs. MDT2 demonstrates, however, that such tailoring is possible and that virtual testbeds can be created to support human factors research.

Developing a multi-service virtual testbed such as MDT2 requires a significant amount of coordination. All the normal problems involved in developing simulator-based training are compounded by a number of factors. These factors include: lack of common terminology between services; differing priorities; differing technical capabilities; and infrequent face-to-face contact. In order to minimize the negative impact of these factors, project personnel must pay careful attention to the basic principles of requirements definition, system engineering, technical documentation, and system testing.

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